NPS-61-85-004

AD-A157 278

NAVAL POSTGRADUATE SCHOOL

Monterey, California

A FLASH X-RAY FACILITY FOR THE
NAVAL POSTGRADUATE SCHOOL

X. K. Maruyama and E. C. Zurey, Jr.

June 1985

Technical Report

Prepared for:
Naval Postgraduate School
Monterey, CA 93943

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

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This report was prepared by:

Xavier K. Maruyama
XAVIER K. MARUYAMA
Adjunct Professor of Physics

Edward C. Zurey, Jr.
EDWARD C. ZUREY, JR.
Lieutenant, USN

Reviewed by:

G E Schacher
GORDON E. SCHACHER, Chairman
Department of Physics

Released by:

JN Dyer
JOHN N. DYER
Dean of Science and Engineering

UNCLASSIFIED

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS-61-85-004	2. GOVT ACCESSION NO. AD-A157278	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Flash X-Ray Facility for the Naval Postgraduate School		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) X. K. Maruyama and E. C. Zurey, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		12. REPORT DATE June 1985
		13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Flash X-Ray Accelerator, Radiation Shielding, Occupational Safety, Radiological Safety.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Flash X-ray accelerator acquired by the Naval Postgraduate School is discussed. Safety considerations in siting this machine are presented.

A FLASH X-RAY FACILITY FOR THE NAVAL POSTGRADUATE SCHOOL

X. K. Maruyama+ and E. C. Zurey, Jr.

Department of Physics
Naval Postgraduate School
Monterey, CA 93943

INTRODUCTION

A Pulsar Model 112A flash X-ray machine has been acquired by the Naval Postgraduate School. This brief report describes the technical aspects of the accelerator and provides documentation so that interested and affected parties may be informed on safety precautions, potential uses and practical considerations for the effective utilization of a major reasource for education and research.

This report is not required by NAVPGSCOLINST 5100.5A and 5100.6A which pertains to the radiation protection program [1,2] at NPS, but is submitted as a matter of courtesy and prudence as some aspects of the use of the flash X-ray machine may fall within the responsibility of safety organizations at NPS. This document constitutes a report to the Safety Manager, the Radiation Protection Officer and the Radiological Safety and Isotopes Committee (RSIC). The device does not fall under the licensing authority of the Nuclear Regulatory Commission as radioactive sources are not involved.

The Naval Postgraduate School has had a long history of education, training and research involving ionizing radiation, NPS has had active programs with a Van de Graaff generator, a reactor, radioactive sources, X-ray machines and a linear electron accelerator. These programs have related to subjects in material science, nuclear reaction and structure studies, solid state physics, beam transport, interaction of radiation with matter and with coherent radiation. Currently the most active program is at the linear electron accelerator which over twenty years has produced some 75 theses. The flash X-ray machine was obtained to expand and complement the capabilities of the linear electron accelerator in the fields of radiation effects on electronic devices, charged particle transport in tenuous and bulk materials, coherent radiation and the study of the properties of intense charge particle beams.

The complementary nature of the flash X-ray machine and the linear electron accelerator are evident when one compares the characteristics of the two accelerators (Table 1). The linac is capable of producing high energy, low current electron beams, whereas the flash X-ray is capable of producing low energy, high current electron beams. Both accelerators are to be used in the radiation effects and space effects programs.

Table 1

Characteristics of Accelerators at the Naval Postgraduate School

	LINAC	PULSAR 112A
Max.Energy	100 MeV	1.75 MeV
Pulse Ref. Rate	60 Hz	1/hr (max 4/hr)
Power Source	RF Klystrons	Marx Bank
Peak Current	-10mA	35 kiloamperes
Average Current	-1mA	not meaningful
Pulse Width	1 msec	30 nsec.

A detailed study[3] has been conducted describing the flash X-ray machine and its impact on the Naval Postgraduate School. The reader is referred to the study for details not covered in this brief report.

PULSAR 112A ELECTRON BEAM/FLASH X-RAY SYSTEM

The Pulsar 112A Electron Beam/Flash X-Ray System is a high power, low maintenance, high reliability, relatively low cost, radiation and electron beam source manufactured by Pulsar Products, Inc., a subsidiary of Physics International Co. Basically it consists of a Marx bank of capacitors charged in parallel and then discharged in series to provide the high accelerating voltage for the electron beam. There is a pulse forming network called the Blumlein which provides a fast pulse

of electrons into an impedance matched load. The active components of the Pulsar 112A are encased in an oil filled tank. Figure 1 illustrates the active components of the Pulsar 112A. Pertinent machine characteristics are given in Table 2.

Table 2

Pulsar 112A Characteristics

Peak Voltage	1.75 MV
Peak Current	35 kiloampere
Pulse Energy Content	1.6 kilojoule
Pulse Width	30 x 10^{-9} sec
Pulse risetime	15 x 10^{-9} sec
Dimensions:	
length	19.7 ft
height	6 ft
width	4.3 ft
weight (with oil)	11,700 lb

SITE SELECTION

Ref. 3 considered installation of the Pulsar 112A in several sites in Halligan Hall. These are designated as sites 1 through 4 in Figure 2. After discussion with the Aeronautical Engineering Department, site 5 has been suggested as an installation site. The choice of adequate site location are dictated by radiation and industrial safety, floor loading, crane access, experimental program space, manpower and other resources requirements.

The linear electron accelerator is located in Halligan Hall. The Pulsar 112A needs to be located in Halligan Hall for the following reasons: a) Many of the experiments require the same equipment so that resources can be shared with the linac. For example, vacuum system components, dosimetry equipment, storage and fast real time oscilloscopes and Nuclear Instrumentation Module (NIM) equipment can be shared. Duplication of these resources could cost several hundred thousand dollars. b) Personnel associated with the linac have experience with ionizing radiation and accelerators. At a minimum, a dedicated professional scientist and one or two technicians would have to be hired in addition to the existing staff if a physically separate location were to be chosen. c) Radiation safety would be enhanced by a central location for sources of ionizing radiation. Physical proliferation of ionizing radiation sources would strain the resources of the RSIC, Radiation Safety Officer and the Safety Manager. d) Educational opportunities would be enhanced by utilizing the complementary characteristics of the linac and the Pulsar 112A. Presently, thesis students reside in room 023 of Halligan Hall and form a positive feedback network among themselves by learning from related experiences. This educational opportunity is induced by the environment and is not available in a classroom instruction situation.

Among the sites considered in Halligan Hall, site 2 was deemed inadequate because of marginal floor loading capacity and the nonavailability of an overhead crane. Physical location of

the Pulsar 112A into site 2 would require considerable reconstruction of some of the structure in room 031. Site 1 was deemed inadequate because of lack of space for propagation and laser excitation experiments. These topics are of current interest in military research. Site 1 is the former 300 ton test loading machine pit and is the most physically restrictive.

Site 3 is the ideal location for the Pulsar 112A. Site 4 and 5 are adequate.

SAFETY CONSIDERATION

Radiation

One important difference between the flash X-ray machine and the linear electron accelerator is that because of the low energy of the electrons no induced radioactivity is possible with the Pulsar 112A.

In considering radiation safety, our goal was to insure that no area accessible to the general public would be exposed to radiation in excess of the permissible dose[4] to the general public according to the Code of Federal Regulation, Title 10, Part 20. This limit is 0.5 rems/year. Ref. 3 details the assumptions and calculations to achieve these considerations, but the final shielding configurations will be determined by actual measurements of the exposure in public access areas. In summary, with a one inch lead housing about an irradiation area and a block house made of 15" of concrete around the accelerator experimental area, no public access area receives more than one

percent of the allowable radiation limits permitted by the Code of Federal Regulations. Most areas would be exposed to radiation several orders of magnitude smaller. Even removing the housing about an irradiation sample the radiation exposure in public access areas are within the allowable limits. The reader is referred to Ref. 3 for details for the calculation of results in Table 3.

Table 3

Calculated Radiation Levels (mrem/pulse) Throughout Halligan Hall for Site 5.

	w/o local shielding	w/local shielding
Restricted Area Perimeter	0.24-0.02	2.4×10^{-2}-2×10^{-4}
Ground Floor Balcony-Overhead	0.24	2.4×10^{-3}
Ground Floor Balcony-Across Basement	0.003	3×10^{-5}
Ground Floor Balcony-Lounge Area	0.001	1×10^{-5}
CFR Limit with Maximum Usage	0.24	

Interlock and Warnings

Access to the experimental area would be interlocked with the Pulsar 112A control panel, so that it is not possible to charge or discharge the Marx bank generators while the area is open. Whenever the machine is capable of producing an electron beam, a flashing warning beacon would be visible in the laboratory area. "Panic" buttons would be accessible in the experimental area to

prevent firing of the Pulsar 112A if personnel are in experimental areas when the machine is capable of operation.

Noxious Gas

Ozone is produced whenever the air is ionized. It is possible to create a hazardous concentration in a small volume if the air is confined. Although the experimental area is of large enough volume to prevent hazardous concentration of ozone, as a further precautionary measure a ventilation system will be installed.

Electrical

High voltage is always a potential hazard in an experimental environment. Access to HV areas will be confined to qualified personnel only. Any work with potential HV components will be done by two people.

Fire Protection

Materials bombarded by intense electron beams will absorb electron energy as heat. The accelerator components are immersed in an electrically insulating oil. Good housekeeping and the availability of fire extinguishers and life support equipment will eliminate fire hazard potential.

SAFETY MONITORING

Personnel associated with the facility will be participants in the LiF TLD program.[2] Experimental and public areas will be monitored with TLD dosimeters to insure that radiation exposure are in compliance with safety limits.[4]

To insure independent assessment of safety aspects, the following activities monitor the accelerator laboratory:

1. NPS Safety Office will involve itself with:

a) design review with emphasis on occupational safety. This document is part of the effort to provide information to the safety office.

b) industrial hygiene review in consultation with NRMC, Oakland.

c) consultations with the Naval Environmental Health Center, Norfolk, VA.

2. The manufacturer, Physics International, employs a shielding consultant available to us at no cost to review our facility plans.

3. The Naval Postgraduate School participates in the LiF TLD program administered by NRMC, Bethesda.

4. The Naval Postgraduate School is inspected periodically by the Naval Energy and Environmental Support Activity, Yorktown, VA.

5. The Radiological Safety Officer inspects and monitors the activities of the facility.

6. The Radiological Safety and Isotopes Committee oversees all aspects of radiological safety at the Naval Postgraduate School.

SUMMARY

This report has described briefly the technical and safety aspects of the Pulsar 112A acquired by the Naval Postgraduate School. With a little planning it will be a safe, effective machine enhancing existing capabilities and creating new opportunities for research and education.

*Permanent Address - National Bureau of Standards, Gaithersburg, MD 20899

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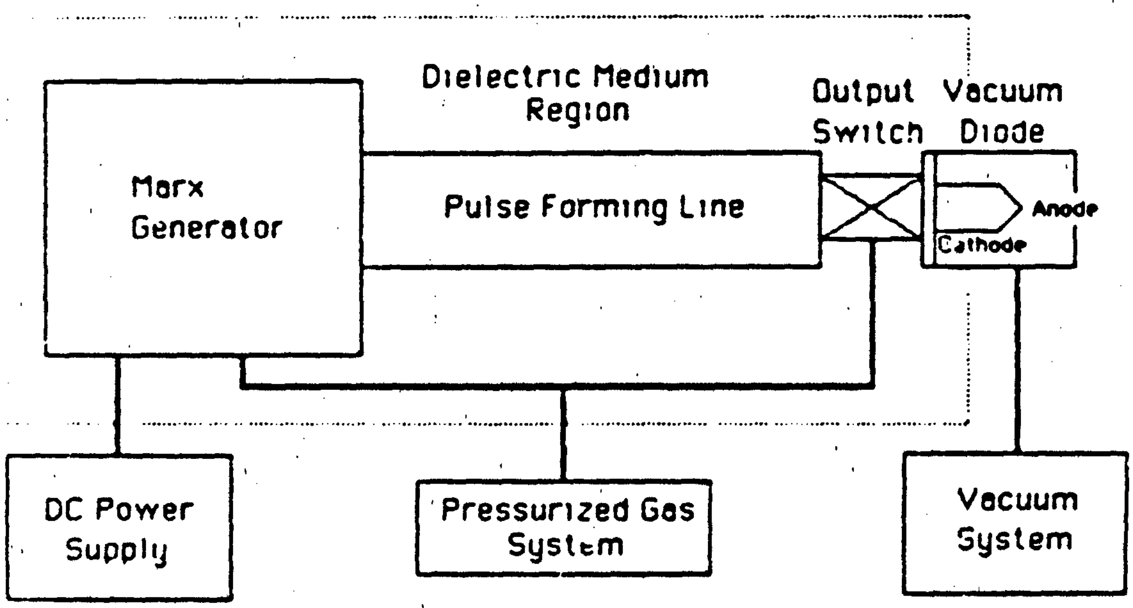

Figure 1: A Block Diagram of a Pulse Charged System

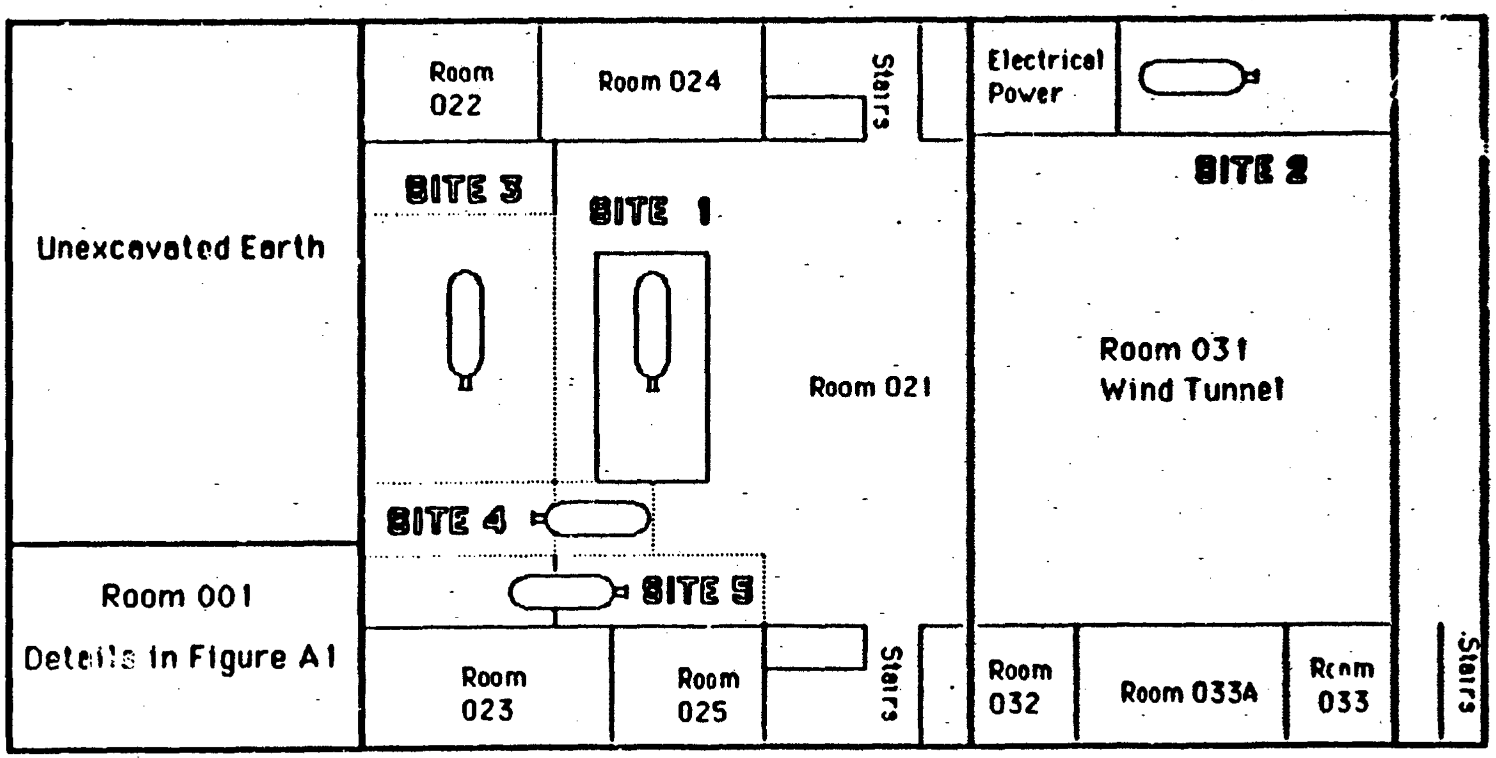

Figure 2: Basement Plan of Halligan Hall

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